

WHAT IS CLAIMED IS:

- 1 1. A bump forming method which comprises the steps of:
 - 2 accumulating a soft solder alloy on the surface of a workpiece;
 - 3 irradiating the accumulated soft solder alloy with at least plasma containing
 - 4 hydrogen; and
 - 5 applying reflow treatment to the soft solder alloy that has been irradiated with
 - 6 at least said hydrogen-containing plasma, thereby forming solder bumps, which will
 - 7 serve as connecting terminals, on the surface of the workpiece.
- 1 2. A bump forming method as claimed in claim 1, wherein the
 - 2 hydrogen-containing plasma irradiation and the reflow treatment are performed in a
 - 3 vacuum.
- 1 3. A bump forming method as claimed in claim 1, wherein the reflow treatment
 - 2 is performed in either an inert gas atmosphere or a reductive atmosphere.
- 1 4. A bump forming method as claimed in claim 1, wherein the irradiating with
 - 2 hydrogen-containing plasma is performed at a temperature lower than the melting
 - 3 point of the soft solder alloy.
- 1 5. A bump forming method as claimed in claim 1, wherein the process gas for
 - 2 generating the hydrogen-containing plasma is a mixed gas containing an inert gas and
 - 3 hydrogen gas that contains hydrogen with a mixing ratio of equal to or more than 3
 - 4 V/V % but less than 8 V/V % calculated in terms of hydrogen molecules.
- 1 6. A bump forming method as claimed in claim 1, wherein the duration of the

2 plasma irradiation is limited to less than two minutes.

1 7. A bump forming method as claimed in claim 1, wherein the reflow treatment
2 is conducted by means of heat radiation in a vacuum.

1 8. A bump forming method as claimed in claim 1, wherein irradiation with
2 fluorine-containing plasma is performed after the hydrogen-containing plasma
3 irradiation.

1 9. A bump forming method as claimed in claim 8, wherein the
2 fluorine-containing plasma contains either one of or both argon and oxygen.

1 10. A bump forming method as claimed in claim 8, wherein the duration and the
2 temperature of irradiation with fluorine-containing plasma are respectively limited to
3 within 60 seconds and a temperature lower than the melting point of the soft solder
4 alloy, the range of permissible temperature including room temperature.

1 11. A bump forming method as claimed in claim 1, wherein the workpiece is
2 preheated at a temperature not higher than 100 °C when conducting the reflow process.

1 12. A bump forming method as claimed in claim 1, wherein irradiation with
2 hydrogen-containing plasma is performed again after the reflow process.

1 13. A soldering method which calls for bringing the soft solder alloy on the
2 surface of a workpiece into contact with the surface of a bonding target, i.e. an object
3 to which said workpiece is intended to be soldered, and thus bonding the surface of
4 the workpiece to the surface of the bonding target by soldering during the reflow
5 process of a bump forming method as claimed in claim 1.

1 14. A solder bump forming apparatus adapted to use a soft solder alloy on the

2 surface of a workpiece to form solder bumps, which will serve as connecting
3 terminals, said solder bump forming apparatus including:

4 a plasma generating means adapted to generate at least hydrogen-containing
5 plasma under a low pressure;

6 a gas supply means for feeding process gas to the plasma generating means;

7 a workpiece exposing means for exposing the soft solder alloy on the surface
8 of the workpiece at least to hydrogen-containing plasma; and

9 a heating means for applying a reflow treatment the soft solder alloy in a
10 vacuum.

1 15. A bump forming apparatus as claimed in claim 14, wherein the plasma
2 generating means is provided with:

3 a high frequency power supply and

4 an electrode connected to said high frequency power supply and adapted to
5 generate plasma,

6 said electrode having:

7 a hollow electrode body adapted to receive the process gas;

8 supply openings that are adapted to feed the process gas and bored in
9 the end of the electrode body facing away from the workpiece; and

10 through holes bored through the electrode body so as to extend from the
11 end where the supply openings are formed to the opposite end.

1 16. A bump forming apparatus as claimed in claim 14, wherein the heating means
2 is provided with:

3 a light source adapted to heat the backside of the workpiece by radiation, and

4 a reflecting mirror for adjusting luminous flux from the light source.

1 17. A bump forming apparatus as claimed in claim 14, wherein the apparatus
2 includes a gas recovery means that defines the flow of the gas that carries plasma
3 generated between said electrode and another electrode to the workpiece, said gas
4 recovery means disposed such that the workpiece is positioned between the gas
5 recovery means and the gas supply means.

1 18. A bump forming apparatus as claimed in claim 14, wherein the heating means
2 includes:

3 a light source disposed at such a location so as not to be exposed to plasma
4 and adapted to heat the workpiece by radiation, and

5 a reflecting mirror adapted to form an optical path extending from the light
6 source to the workpiece.

1 19. A bump forming apparatus as claimed in claim 14, wherein the apparatus
2 includes a gas supply means for supplying a process gas, which is a mixed gas
3 containing an inert gas and hydrogen gas that contains hydrogen with a mixing ratio of
4 equal to or more than 3 V/V % but less than 8 V/V % calculated in terms of hydrogen
5 molecules.

1 20. A bump forming apparatus as claimed in claim 14, wherein the apparatus
2 includes a high frequency power supply having a frequency of either 13.56 MHz or

3 2.45 GHz.

1 21. A bump forming apparatus as claimed in claim 14, wherein the plasma
2 generating means is adapted to generate fluorine-containing plasma in addition to the
3 aforementioned hydrogen-containing plasma, said fluorine-containing plasma
4 containing either one of or both argon and oxygen.

1 22. A soldering apparatus including:

2 a bump forming apparatus as claimed in claim 14;

3 a positioning means for aligning and bringing the soft solder alloy on the
4 surface of a workpiece that has been exposed to plasma and the surface of a bonding
5 target into contact with each other; and

6 a heating means for applying reflow treatment to the film of the soft solder
7 alloy, thereby soldering the surface of the workpiece and the surface of the bonding
8 target together.

1 23. A bump forming method for forming bumps, which will serve as connecting
2 terminals, on the surface of a workpiece by following the procedure that comprises the
3 steps of:

4 roughening the surface of a soft solder alloy accumulated on the surface of
5 the workpiece;

6 applying the roughened surface of the soft solder alloy surface reforming
7 treatment that calls for forming a layer containing fluorine on the surface of the soft
8 solder alloy; and

9 performing reflow of the soft solder alloy that has undergone said surface
10 reforming treatment.

1 24. A bump forming method as claimed in claim 23, wherein the surface
2 roughening treatment is performed by using plasma excitation of an inert gas to which
3 hydrogen has been added.

1 25. A bump forming method as claimed in claim 24, wherein the quantity of the
2 hydrogen added ranges from equal to or more than 3 V/V % to less than 8 V/V %.

1 26. A bump forming method as claimed in claim 24, wherein argon is used as the
2 inert gas.

1 27. A bump forming method as claimed in claim 23, wherein the surface
2 reforming treatment is performed by using plasma excitation of a mixed gas which
3 contains a fluorine compound or fluorine compounds, and to which either one of or
4 both oxygen and argon are added.

1 28. A bump forming method as claimed in claim 27, wherein the fluorine
2 compound consists of at least one of the compounds selected from among carbon
3 fluoride compounds, sulfur hexafluoride and nitrogen trifluoride.

1 29. A presoldering treatment method which comprises the steps of:

2 roughening the surface of solder bumps of a soft solder alloy formed on the
3 surface of a workpiece, and

4 forming a layer containing fluorine on the roughened surface of the solder
5 bumps, thereby applying surface reforming treatment to the surface of the solder
6 bumps.

1 30. A presoldering treatment method as claimed in claim 29, wherein the surface
2 roughening treatment is performed by using plasma excitation of an inert gas to which
3 hydrogen has been added.

1 31. A presoldering treatment method as claimed in claim 30, wherein the quantity
2 of the hydrogen added ranges from equal to or more than 3 V/V % to less than 8
3 V/V %.

1 32. A presoldering treatment method as claimed in claim 30, wherein argon is
2 used as the inert gas.

1 33. A presoldering treatment method as claimed in claim 29, wherein the surface
2 reforming treatment is performed by using plasma excitation of a mixed gas which
3 contains a fluorine compound or fluorine compounds, and to which either one of or
4 both oxygen and argon are added.

1 34. A presoldering treatment method as claimed in claim 33, wherein the fluorine
2 compound consists of at least one of the compounds selected from among carbon
3 fluoride compounds, sulfur hexafluoride and nitrogen trifluoride.

1 35. A soldering method for bonding together a plurality of workpieces by
2 soldering, said soldering method comprising the steps of:

3 roughening the surface of solder bumps of a soft solder alloy formed on one
4 or more workpieces;

5 forming a layer containing fluorine on the roughened surface of the solder
6 bumps, thereby applying surface reforming treatment to the surface of the solder
7 bumps; and

8 bringing said one or more workpieces having the solder bumps that have
9 undergone the surface roughening treatment and the surface reforming treatment into
10 contact with other workpiece or workpieces and, in this state, performing reflow of
11 these workpieces.

1 36. A soldering method as claimed in claim 35, wherein the surface roughening
2 treatment is performed by using plasma excitation of an inert gas to which hydrogen
3 has been added.

1 37. A soldering method as claimed in claim 36, wherein the quantity of the
2 hydrogen added ranges from equal to or more than 3 V/V % to less than 8 V/V %.

1 38. A soldering method as claimed in claim 36, wherein argon is used as the inert
2 gas.

1 39. A soldering method as claimed in claim 35, wherein the surface reforming
2 treatment is performed by using plasma excitation of a mixed gas which contains a
3 fluorine compound or fluorine compounds, and to which either one of or both oxygen
4 and argon are added.

1 40. A soldering method as claimed in claim 39, wherein the fluorine compound
2 consists of at least one of the compounds selected from among carbon fluoride
3 compounds, sulfur hexafluoride and nitrogen trifluoride.

1 41. A bump forming apparatus including:

2 a surface roughening device for roughening the surface of a soft solder alloy
3 accumulated on a workpiece;

4 a surface reforming device for performing surface reforming treatment by

5 forming a fluorine containing layer on the roughened surface of the soft solder alloy;
6 and

7 a thermal melting unit for performing reflow of the soft solder alloy having
8 the reformed surface, thereby forming solder bumps, which will serve as connecting
9 terminals, on the surface of said workpiece.

1 42. A bump forming apparatus as claimed in claim 41, wherein:

2 the surface roughening device is a plasma exciting device adapted to roughen
3 the surface of a soft solder alloy by means of plasma excitation, and

4 the plasma exciting device and the surface reforming device are respectively
5 operated in separate and different atmospheres without a pause between operation of
6 the plasma exciting device and the operation of the surface reforming device.

1 43. A presoldering treatment apparatus including:

2 a surface roughening device for roughening the surface of solder bumps of a
3 soft solder alloy formed on a workpiece, and

4 a surface reforming device for performing surface reforming treatment by
5 forming a fluorine containing layer on the roughened surface of the solder bumps.

1 44. A presoldering treatment apparatus as claimed in claim 43, wherein:

2 the surface roughening device is a plasma exciting device adapted to roughen
3 the surface of a soft solder alloy by means of plasma excitation, and

4 the plasma exciting device and the surface reforming device are respectively
5 operated in separate and different atmospheres without a pause between operation of

6 the plasma exciting device and the operation of the surface reforming device.

1 45. A presoldering treatment apparatus as claimed in claim 43, wherein the
2 surface roughening device is adapted to roughen the surface of the solder bumps of the
3 soft solder alloy in a mechanical way.

1 46. A soldering apparatus which is adapted to solder together a plurality of
2 workpieces and includes:

3 a surface roughening device for roughening the surface of solder bumps of a
4 soft solder alloy formed on one or more workpieces;

5 a surface reforming device for performing surface reforming treatment by
6 forming a fluorine containing layer on the roughened surface of the solder bumps; and

7 a thermal melting unit for bringing one or more workpieces having the solder
8 bumps that have undergone the surface roughening treatment and the surface
9 reforming treatment into contact with other workpiece or workpieces and, in this state,
10 performing reflow of these workpieces.

1 47. A soldering apparatus as claimed in claim 46, wherein:

2 the surface roughening device is a plasma exciting device adapted to roughen
3 the surface of a soft solder alloy by means of plasma excitation, and

4 the plasma exciting device and the surface reforming device are respectively
5 operated in separate and different atmospheres without a pause between operation of
6 the plasma exciting device and the operation of the surface reforming device.

1 48. A soldering apparatus as claimed in claim 46, wherein the surface roughening

2 device is adapted to mechanically roughen the surface of the solder bumps of the soft
3 solder alloy.

1 49. A presoldering treatment method as claimed in claim 29, wherein the
2 roughening step further comprising the step of:

3 mechanically roughening the surface of solder bumps formed on a solder
4 bump plate by means of a roughening member comprising:

5 a bumpy surface comprising minute indentations and protrusions
6 disposed on the bumpy surface.

1 50. A presoldering treatment method as claimed in claim 49, further comprising
2 the step of:

3 rolling a roller having a bumpy surface including minute indentations and
4 protrusions disposed on the bumpy surface, which contacts the surface of the solder
5 bumps during movement; the movement includes moving at least one of said roller
6 against the solder bumps and moving the solder bumps against the roller
7 simultaneously flattening and roughening, the surface of the solder bumps by
8 contacting the roller.

1 51. A presoldering treatment method as claimed in claim 49, further comprising
2 the steps of:

3 placing a flat plate, having a bumpy surface including minute indentations and
4 protrusions disposed on the bumpy surface, which contact the surface of the solder
5 bumps so the bumpy surface rests on the solder bumps

6 applying a given load to the flat plate so that the surface of the solder bumps
7 is simultaneously flattened and roughened by the flat plate.

1 52. A presoldering treatment method as claimed in claim 49, further comprising
2 the step of:

3 placing the solder bump plate on a flat plate having a bumpy surface
4 including minute indentations and protrusions on the bumpy disposed surface, so
5 solder bumps formed on said solder bump plate rest on the bumpy surface of the flat
6 plate,

7 applying a given load to the solder bump plate so that the surface of the
8 solder bumps is simultaneously flattened and roughened by the flat plate.

1 53. A presoldering treatment method as claimed in claim 52, further comprising
2 the step of:

3 scratching, rubbing, or scrubbing the solder bump plate while applying a
4 given load to the solder bump plate.

1 54. A presoldering treatment method as claimed in claim 49, wherein the surface
2 roughening treatment further comprising the step of:

3 repeating a plurality of roughening actions to the surface of the same solder
4 bumps.